FRDA Report 112

Effect of Manual Treatment Timing on Red Alder Regrowth and Conifer Response

by
Frank Pendl and Brian D'Anjou

B.C. Ministry of Forests
Vancouver Forest Region
4595 Canada Way
Burnaby, B.C.
V5G 4L9

February 1990

ECONOMIC & REGIONAL DEVELOPMENT AGREEMENT

Canada

BC

90-05857/

Funding for this publication was provided by the Canada-British Columbia Forest Resource Development Agreement - a five year (1985-90) $300 million program cost-shared equally by the federal and provincial governments.

Canadian Cataloguing in Publication Data

Pendl, Frank.
Effect of manual treatment timing on red alder regrowth and conifer response

(FRDA report, ISSN 0835-0752 ; 112)

Issued under Canada-BC Forest Resource Development Agreement.
Co-published by B.C. Ministry of Forests.
"Canada/BC Economic & Regional Development Agreement."
Includes bibliographical references.
ISBN 0-7726-1101-7

1. Red alder - Control - British Columbia - Okeover Inlet Region. 2. Red alder - British Columbia - Okeover Inlet Region - Growth. 3. Douglas fir - British Columbia - Okeover Inlet Region - Growth. 4. Abies grandis - British Columbia - Okeover Inlet Region - Growth. I. D'Anjou, Brian. II. Canada. Forestry Canada. III. British Columbia. Ministry of Forests. IV. Canada-British Columbia Forest Resource Development Agreement. V. Canada/BC Economic & Regional Development Agreement. VI. Title. VII. Series.

SD397.R18P46 1990 634.9'73976 C90-09102-1

© 1990 Government of Canada,
Province of British Columbia

This is a joint publication of Forestry Canada and the British Columbia Ministry of Forests.

Produced and distributed by the Ministry of Forests, Research Branch.

For additional copies and/or further information about the Canada-British Columbia Forest Resource Development Agreement, contact:

Forestry Canada
Pacific Forestry Centre
506 West Burnside Road
Victoria, B.C. V8Z 1M5
(604) 388-0600

or

B.C. Ministry of Forests
Research Branch
31 Bastion Square
Victoria, B.C. V8W 3E7
(604) 387-6719

SUMMARY

Red alder (*Alnus rubra* Bong.) is capable of dominating a range of sites following harvesting of coastal forests, quickly overtopping slower growing conifers. Manual cutting is an alternative to herbicides for controlling red alder but the species can resprout after cutting and continue to compete with the conifers for light. This study was initiated to explore the effects of timing of cut on resprouting behaviour of red alder. Circular brush saws were used to cut a 4-year-old stand of red alder overtopping planted Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and grand fir (*Abies grandis* (Dougl. *ex* D. Don)) seedlings on a site near Powell River, B.C. Cutting treatments were applied at five different times between June 7 and September 1, 1983.

During the first two growing seasons after treatment, alder survival was lower when stems had been cut later in the growing season. During subsequent years, treatment effects were masked by high alder mortality in all control and treatment plots, possibly as a result of moisture stress and the disease *Melancomium*.

Cutting resulted in a significant reduction in alder height over the 5 years of measurement, but did not significantly affect the number of sprouts arising from surviving stumps.

Treatments had no significant effect on post-treatment height or survival of grand fir. Stem diameter of grand fir was significantly greater in the treated plots for the first two growing seasons, but treatments did not differ significantly in subsequent years.

Three years after treatment, height of Douglas-fir was significantly lower in control plots where alder was previously cut in 1980 but continues to overtop over 90% of the Douglas-fir saplings. At five years, no significant differences in Douglas-fir stem diameter or survival were evident.

ACKNOWLEDGEMENTS

This project was funded under the Canada-British Columbia Forest Resource Development Agreement (FRDA) and under the NEED federal funding program. Thanks go to the staff of the Powell River Forest District for their co-operation in establishing this trial. Silver Ring Forestry Ltd. (Powell River) was responsible for the 3rd- and 5th-year remeasurements. Michael Conway-Brown and company completed the manual treatments and the early remeasurements. Additional thanks go to Mel Scott, Phil Comeau, and others who reviewed earlier drafts of the report.

TABLE OF CONTENTS

SUMMARY iii

1 INTRODUCTION 1

2 OBJECTIVES 1

3 METHODS AND MATERIALS 1

3.1 Location and Description of Study Area 1

3.2 Experimental Design 4

3.3 Method of Brushing 4

3.4 Alder and Conifer Measurements 5

3.5 Method of Analysis 5

4 RESULTS 5

4.1 Red Alder Response 6

4.2 Conifer Response 7
4.2.1 Grand fir 7
4.2.2 Douglas-fir 10

5 DISCUSSION AND CONCLUSIONS 13

6 REFERENCES 15

APPENDICES

1 Description of planting stock 16

2 Weather records, 1983 16

3 Conifer condition codes 17

4 ANOVA of grand fir pretreatment stem diameter and height 18

5 ANOVA results of grand fir stem diameter increment, by growing season 18

6 ANOVA of grand fir height increment, by growing season 19

7 Fifth-year conifer survival and sample size by species, pretreatment status, and treatment 19

8 Fifth-year condition of saplings by species, treatment, and block 20

9 ANOVA of pretreatment height and stem diameter of Douglas-fir saplings 20

10 ANOVA of Douglas-fir height growth, by growing season 21

11 ANOVA of Douglas-fir stem diameter increment, by growing season 21

TABLES

1 Pretreatment survey of the trial site - spring, 1983. Standard deviation in brackets 3

2 Treatment periods for the manual control of red alder 4

3 ANOVA design 5

4 ANOVA results of red alder mortality, number of sprouts, and sprout height: 5th-year results 7

5 Red alder stems per hectare by pretreatment block and treatment: 5th-year results 8

6 ANOVA results of grand fir height and stem diameter: total (1988) and 5-year increment (1983-1988) and total volume. Sums of squares are in parentheses. 9

7 Summary of ANOVA results of 5th-year grand fir survival 10

8 ANOVA results on Douglas-fir height and stem diameter: total (1988) and 5-year increment (1983-1988). Sums of squares are in parentheses. 11

9 ANOVA results of 5th-year Douglas-fir survival 13

FIGURES

1 Location of trial area 2

2 Trial design 4

3 Red alder survival by block, treatment, and time 6

4 Red alder height by block, treatment, and time 6

5 Number of red alder sprouts per stump by block, treatment, and time 7

6 Grand fir total height by block, treatment, and time 8

7 Grand fir stem diameter by block, treatment, and time 8

8 Grand fir stem volume by block, treatment, and time 10

9 Percentage of grand fir overtopped by red alder, by block, treatment, and time 10

10 Douglas-fir total height by block, treatment, and time 11

11 Douglas-fir stem diameter by block, treatment, and time 11

12 Douglas-fir stem volume by block, treatment, and time 12

13 Percentage of Douglas-fir overtopped by red alder, by block, treatment, and time 12

1 INTRODUCTION

Red alder (*Alnus rubra* Bong.), is a common deciduous tree species found throughout the coastal area of British Columbia. Because of its rapid juvenile height growth and ability to form dense stands, red alder is capable of dominating recently logged sites and outcompeting conifers principally for growing space and light. Reduced conifer growth rates and survival can be the result of heavy alder competition.

Several herbicides are effective control agents against red alder. However, since many forest plantations are near population centres or close to important water bodies, local public interest frequently favours the use of a non-chemical treatment. One possible alternative to the use of herbicides for red alder control is manual cutting with chain saws or circular brush saws.

The effectiveness of manual control of red alder has not been reported extensively. Rather, the rapid resprouting and growth of red alder and other vegetation species after cutting has led most researchers to examine the use of herbicides. Roberts (1980) studied the impact of timing on the effectiveness of manual brush cutting in releasing Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) from a variety of brush species, including red alder. Also, Harrington (1983) studied the effects of tree age, timing of cut, stump height, and angle and aspect of cut on the early resprouting of red alder. Hoyer and Belz (1984) examined the influence that time of cutting had on the ability of red alder to sprout. All of these studies generally indicate that alder's ability to resprout is minimized if it is cut following full leaf development and late in the growing season. Harrington also suggested that stump mortality could be maximized if the alder were cut as low to the ground as possible. An investigation of the sprouting habits of red alder and the practicality of manual control in coastal British Columbia began in 1983 on a stand of immature conifer and red alder near Powell River. The site, gently sloping and relatively clear of debris, suited the application of circular brush saws for the cutting of red alder.

2 OBJECTIVES

The objectives of the trial were:

1. To examine the effects of timing of cut on the resprouting of red alder. Five treatment periods between June 7 and September 1 were established to identify the most effective time to cut (minimum alder regrowth).
2. To determine the effect of alder removal on subsequent conifer growth and condition.

This report summarizes results over five growing seasons after treatment.

3 METHODS AND MATERIALS

3.1 Location and Description of Study Area

The trial was established at the head of Okeover Inlet, about 16 km northwest of Powell River, B.C. (Figure 1). The site is located within the Wetter Coastal Douglas-fir Biogeoclimatic Subzone at an elevation between 80 and 120 m above sea level. Before logging, an immature stand of Douglas-fir between 41 and 60 years of age occupied the site, with a minor component of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). The stand was logged between 1976 and 1978 to control the spread of root rot (*Phellinus weirii*) infecting the Douglas-fir.

In 1978, a caterpillar tractor extracted stumps on 14.2 ha of the site in an attempt to isolate root rot infections. The resulting debris was collected into piles but not burned. This stump removal operation created a disturbed soil layer between 6 and 12 cm in depth, much deeper in some areas. Soils were identified as Gleyed Humo-Ferric Podzol in the lower-most portion of the study area and a Duric Humo-Ferric Podzol, in the middle and upper portion (F. Nuszdorfer, pers. comm., 1983). The majority of the study area was judged to have a soil moisture regime ranging from subxeric to submesic and a nutrient regime of poor to medium, because of the low organic matter content of the soil combined with coarse soil texture.

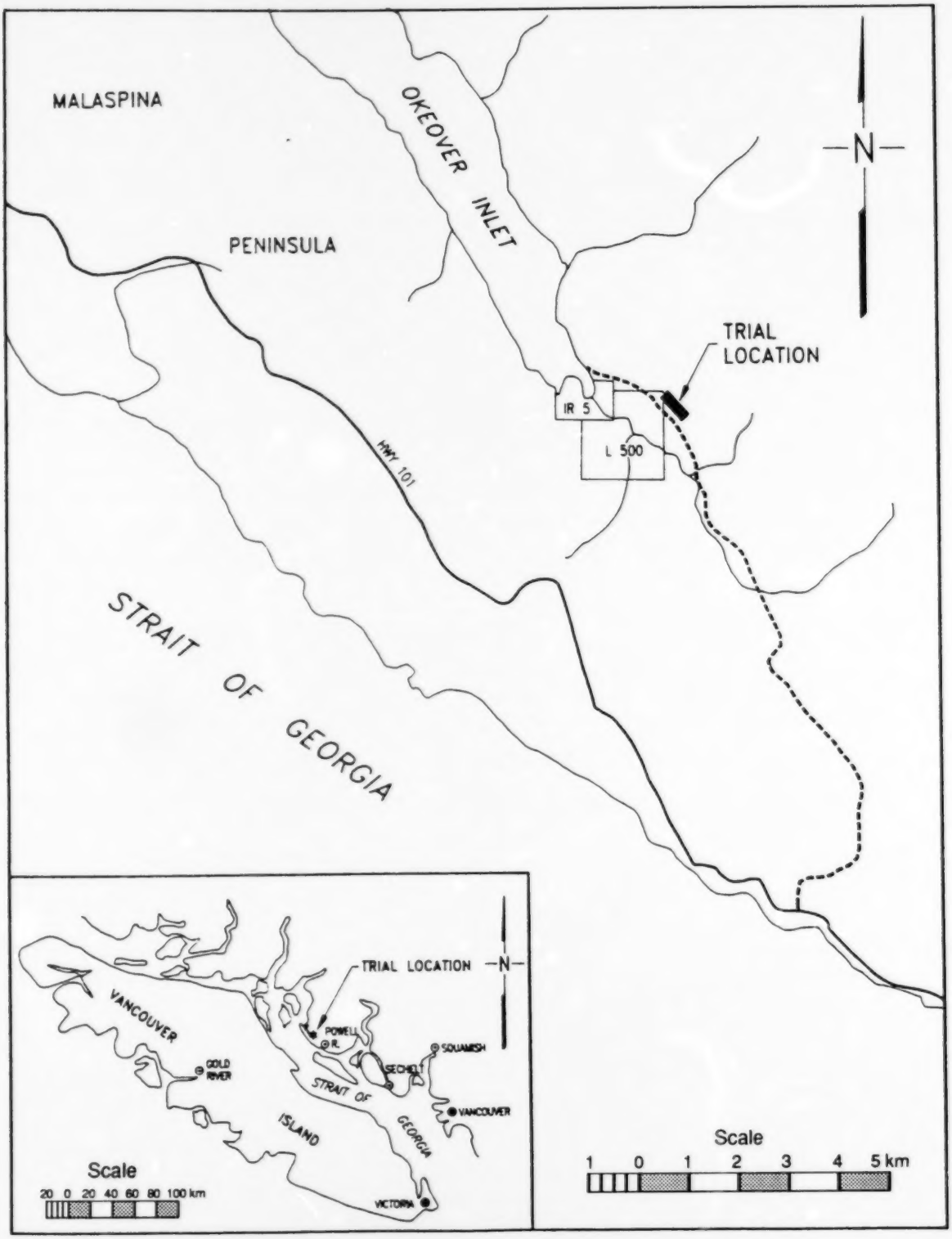

FIGURE 1. Location of trial area.

In the spring of 1979, the site was planted with a mixture of Douglas-fir and grand fir (*Abies grandis* (Dougl. *ex* D. Don)) (stock description in Appendix 1). Surveys in the spring of 1980 indicated high survival of both species (Douglas-fir: 90%; grand fir: 100%). A survey of the site in the fall of 1980 revealed that a red alder stand had become established. The disturbed mineral soil proved ideal for alder regeneration and rapid early height growth allowed it to overtop the conifer plantation. In November and December of that year, 9.5 ha of alder were manually treated with chain saws. Seven months later, the cut alder had resprouted, with sprouts averaging 1 m in height.

A pre-treatment survey within the trial area was completed in the spring of 1983. One circular subplot (3.99 m radius in blocks A and B; 1.78 m radius in blocks C and D) was randomly established in each of the 24 treatment plots (Figure 2). The subplots established in blocks C and D were smaller because of the greater density of red alder in those blocks compared to blocks A and B. The number, diameter (1.3 m above ground), and height of alder stems within the subplots were recorded, as well as number of stems of any other tree species. Number of conifer seedlings, both planted and natural, was also recorded. The pre-treatment survey indicated good stocking of the planted Douglas-fir and grand fir (Table 1). Naturally established western hemlock (250 stems per hectare) and lodgepole pine (50 stems per hectare) were also found. Alder stumps in blocks C and D generally had multiple sprouts, the typical growth habit after manual cutting, leading to higher alder density than found in the untreated blocks A and B (51 600 versus 4400 stems per hectare, respectively).

TABLE 1. Pretreatment survey of the trial site - spring, 1983. Standard deviation in brackets.

	Area not manually brushed		Area manually brushed in 1980	
Species	**Mean (S.D.)**	**Sample size**	**Mean (S.D.)**	**Sample size**
Red alder				
(a) stems per hectare	4 400 (1 700)	12 plots	51 600 (16 800)	12 plots
(b) diameter (cm)	3.5 (0.8)	262 trees	1.2 (0.2)	619 trees
(c) height (cm)	440 (88)	12 trees	330 (55)	12 trees
Grand fir				
(a) stems per hectare	220 (250)	12 plots	500 (674)	12 plots
(b) height	124 (37.5)	153 trees	134 (45.2)	122 trees
Douglas-fir				
(a) stems per hectare	1 350 (475)	12 plots	2 250 (1 700)	12 plots
(b) height (cm)	171 (53.2)	339 trees	170 (58.1)	387 trees

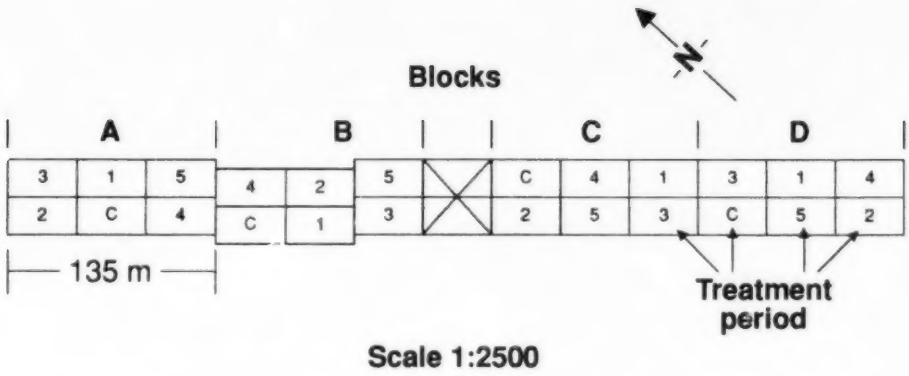

FIGURE 2. Trial design.

3.2 Experimental Design

The study area was divided into four blocks (Figure 2). Blocks C and D contained alder manually treated in the fall of 1980 (pretreated). Blocks A and B contained alder left untreated (not pretreated). Each block (135 X 50 m) contained six treatment plots, one plot (25 X 45 m) for each of the five treatment periods plus an uncut control. Treatments were randomly assigned within each block. The treatment periods for this trial are summarized in Table 2.

TABLE 2. Treatment periods for the manual control of red alder

Plot number	Treatment period
1	June 7 - 8, 1983
2	July 5 - 7, 1983
3	July 19 - 21, 1983
4	Aug. 2 - 4, 1983
5	Aug. 30 - Sept. 1, 1983
C	Control - Untreated

3.3 Method of Brushing

A variety of light-weight, rotary shaft-clearing saws were used to cut the alder, including the Huskavarna 165, Stihl FS08, and Shindaiwa B-40. A variety of blades were also tested, including a 12-inch Stihl, 50-tooth saw, and regular circular saw blade with a radical set and 30-40 teeth. A complete evaluation of the clearing saws and blades used in this trial are summarized in an operations report and equipment assessment by Conway-Brown (1985). Workers were instructed to cut alder low to the ground and level, characteristics said to maximize alder mortality. Between three and five workers did the cutting, with a maximum of two workers cutting in a plot at a time. Formal production figures for the cutting operation were not collected, but four cutters completed the four plots in 1.5-2 days (0.1-0.15 ha per man-day). Saw breakdowns were common, reducing worker productivity. Temperature and humidity readings were taken on-site during the first four treatment periods (Appendix 2).

3.4 Alder and Conifer Measurements

After alder cutting was completed on a plot, 50 alder stumps and 50 planted conifers were randomly selected from computer-generated random point maps. Each sampled alder stump and conifer was marked with a 4-ft cedar stake to which a plastic number tag was attached. Stump height and diameter, angle of cut (for alder in blocks A+B), and number of cut sprouts on each sampled alder stump (in blocks C+D) were measured. Subsequent remeasurements of alder included number of new sprouts and height of tallest sprout. Conifer measurements began during the season of treatment and included species, height (using telescoping height pole), stem diameter (measured 20 cm above ground level using calipers), and condition (Appendix 3). The degree to which each surviving conifer was overtopped was assessed using a three-class scale:

i. free-growing - surrounding vegetation below the height of the conifers top whorl;

ii. threatened - surrounding vegetation reaching height, but not overtopping the conifers top whorl;

iii. overtopping - conifer top whorl overtopped by surrounding vegetation.

Both alder and conifers were remeasured and assessed one, two, three, and five growing seasons after treatment. Six circular assessment plots (10 m^2) were randomly established in each treatment unit in the spring of 1989, within which the number of red alder stems and cover and height of the three most abundant vegetation species (based on cover) were measured.

3.5 Method of Analysis

The statistical significance (95%) of treatment periods on conifer response and red alder regrowth was determined. The analysis of variance (ANOVA) design in Table 3 was used to test the significant effect of treatment time on both conifer and alder growth response. Survival figures underwent arcsine transformation before analysis to transform the resultant data to a nearly normal distribution (Zar 1984).

TABLE 3. ANOVA design

Source	Symbol	Degrees of freedom	Error term
Pre-treatment	P	1	B(P)
Block	B(P)	2	—
Treatment	T	5	B(P) x T
Pre-treatment x Treatment	P x T	5	B(P) x T
Block x Treatment	B(P) x T	10	—

4 RESULTS

In the following analysis, blocks C and D (previously manually treated in 1980) are collectively termed "pretreated." Blocks A and B, where alder had not been treated before this trial, are called "not pretreated."

In 1984, the first growing season following treatment, 409 mm of rain fell between March 1 and July 31 as recorded at the Powell River airport. Between March and July of the following year (1985), only 65% of this amount (224 mm) was recorded. Moisture stress symptoms appeared in both conifers and red alder in the form of dropping leaders and stems by June 1985. Rainfall levels increased in 1986, to 381 mm between the same time period.

4.1 Red Alder Response

During the two growing seasons following cutting, alder mortality was significantly different between treatments. Cutting later in the growing season resulted in higher mortality (Figure 3). However, by the fifth growing season after cutting, alder survival was no longer significantly different between treatment or pretreatment blocks. Red alder survival decreased in most treatments since the 3rd-year assessment, now averaging 18% in blocks A+B and 30% in blocks C+D. Alder mortality in the control plots began in the second season following cutting. Symptoms of the disease *Melancomium* spp. were identified in November 1986 (J. Beale, pers. comm.) and may be associated with severe moisture stress in 1984, indicated by symptoms of drooping foliage and branches. The pathogen effectively masked differences in alder mortality between treatments.

In four of the five cutting periods, red alder has reached or surpassed pretreatment height (Figure 4). Mean total height of red alder sprouts is not significantly different between pretreatment blocks, but is different between treatments with alder in the control which is taller than in the treated plots (Table 4). However, alder height growth in the last 2 years (fourth and fifth growing seasons) is less in the control plots than in the treated plots.

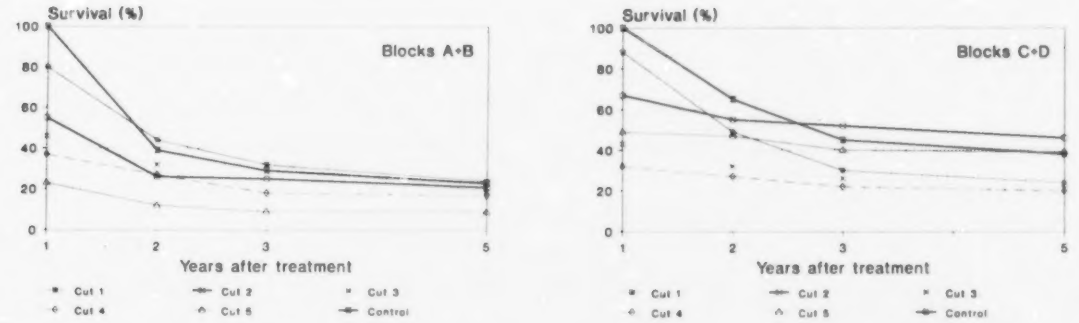

FIGURE 3. Red alder survival by block, treatment, and time.

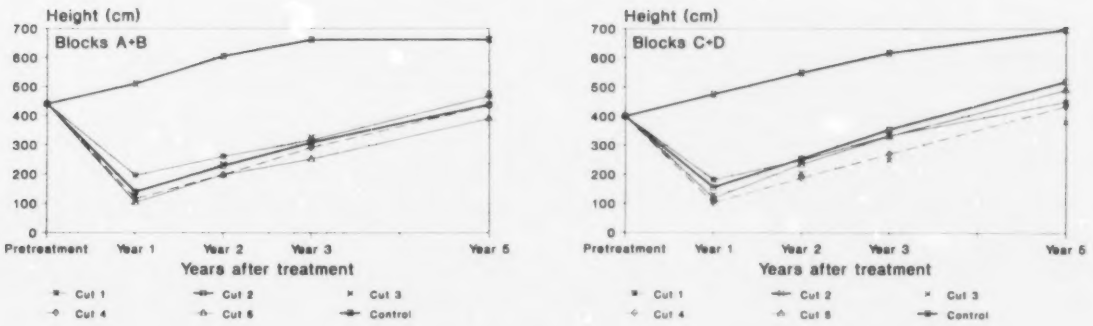

FIGURE 4. Red alder height by block, treatment, and time.

TABLE 4. ANOVA results of red alder mortality, number of sprouts, and sprout height: 5th-year results

Source	Error term	Total mortality		Number of sprouts		Sprout height	
		SS	Prob.	SS	Prob.	SS	Prob.
P	B(P)	0.13	.220	35.5	.081	54 380	.056
T	B(P)xT	0.09	.394	69.7	.051	746 405	.008
P x T	B(P) x T	0.11	.271	22.8	.426	288 920	.122
B(P) x T	—	0.11	—	35.8	—	262 006	—
B(P)	—	0.15	—	42.2	—	250 288	—

The number of alder sprouts from surviving stumps has decreased since the 3rd-year assessment, with no significant differences between pretreatment blocks or between treatments (Figure 5). Early trends indicated that cutting later in the growing season led to fewer sprouts from surviving alder stumps, but this trend disappeared in later years.

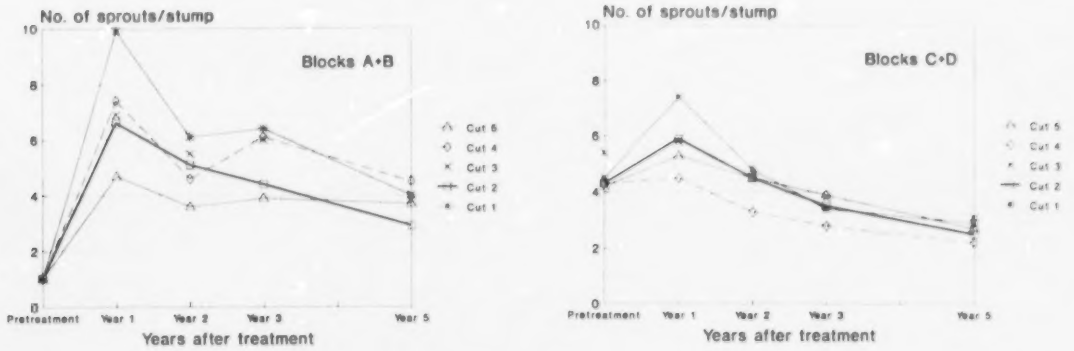

FIGURE 5. Number of red alder sprouts per stump by block, treatment, and time.

The number of surviving alder stems per hectare is summarized by block and treatment in Table 5. Alder density remains higher in blocks C+D. The trend of better alder control (lower density) following cutting later in the growing seasons is strongest in blocks A+B. Salal (*Gaultheria shallon* Pursh) is the most abundant non-crop vegetation on the site, averaging 11% cover over the whole site. Arbutus (*Arbutus menziesii* Pursh), ocean spray (*Holodiscus discolor* (Pursh) Maxim.), trailing rubus (*Rubus pedatus* Sm.), bigleaf maple (*Acer macrophyllum* Pursh), and bracken fern (*Pteridium aquilinum* (L.) Kuhn var. *pubescens* Underw.) were also found on the site, each averaging less than 5% cover.

4.2 Conifer Response

4.2.1 Grand fir

Before treatment, grand fir stem diameter and total height were not significantly different between treatments or between pretreatment blocks (Appendix 4). Total grand fir height is summarized in Figure 6 and total stem diameter in Figure 7.

TABLE 5. Red alder stems per hectare by pretreatment block and treatment: 5th-year results

Treatment	Block	
	Not pretreated (Blocks A+B) (Pretreatment = 4 400)	Pretreated (Blocks C+D) (Pretreatment = 51 600)
June 7-8	3 340	5 511
July 5-7	6 346	9 603
July 19-21	4 676	5 845
August 2-4	2 839	6 764
Aug. 30 - Sept. 1	2 254	8 100
Control	835	6 263

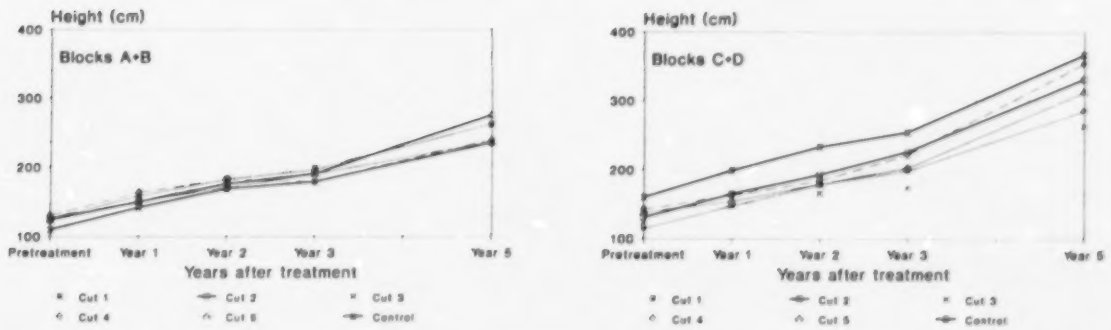

FIGURE 6. Grand fir total height by block, treatment, and time.

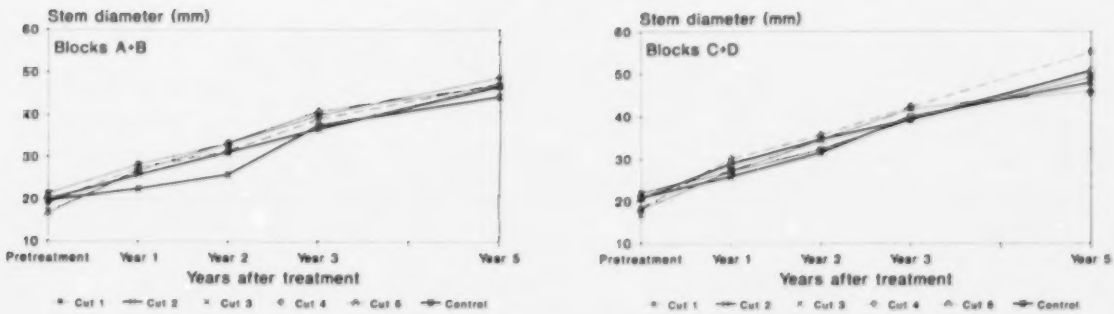

FIGURE 7. Grand fir stem diameter by block, treatment, and time.

Annual grand fir height growth was not significantly different between treatments in the first three growing seasons following treatment (Appendix 5). Similarly, total 5-year grand fir height growth was not significantly different between treatments (Table 6), although height growth was greater in pretreated blocks C+D than in blocks A+B (not pretreated). Grand fir height growth has increased during the last two growing seasons over 3rd-year levels. Dead tops in cut 4 in blocks A+B resulted in negative height increment in the third season following treatment.

TABLE 6. ANOVA results of grand fir height and stem diameter: total (1988) and 5-year increment (1983-1988) and total volume. Sums of squares are in parentheses.

		Height		Diameter		
Source	Error	Incr. 1983-88	Total 1988	Incr. 1983-88	Total 1988	Total volume 1988
P	B(P)	.0406 (100 440)	.0463 (228 530)	.9785 (303)	.4034 (143)	.0045 (3.2×10^7)
T	B(P) x T	.2685 (18 742)	.2356 (75 700)	.6280 (716)	.6129 (712)	.2213 (2.3×10^7)
P x T	B(P) x T	.1582 (25 177)	.0905 (121 292)	.5275 (885)	.4837 (931)	.1818 (2.6×10^7)
B(P) x T	—	— (24 172)	— (92 175)	— (2 009)	— (1 934)	— (2.7×10^7)
B(P)	—	— (8 683)	— (22 753)	— (666)	— (259)	— (2.8×10^5)

Grand fir stem diameter growth was significantly different between treatments in the third growing season following treatment and strongly affected by treatment in the first season following cutting. This initial response reflected enhanced stem diameter growth response (Appendix 6). However, grand fir 5-year stem diameter increment and total stem diameter were not different between either treatments or pretreatment blocks. Diameter increment in the 4th and 5th year combined showed a reduction in some treatments and a slight increase in other treatments over 3rd-year levels. Stem diameter and height growth reduction in the second growing season can partly be attributed to moisture stress in a relatively dry growing season. A 300% increase in stem diameter growth occurred in the control blocks following the large increase in alder mortality in the third season following treatment.

Grand fir volume growth was significantly greater in blocks C+D than in blocks A+B, but was not significantly different between treatments (Figure 8). (Equations for estimating stem volume are from Kovats [1977]; equations for Douglas-fir are used for both conifer species.)

Fifth-year grand fir survival did not differ significantly between treatment and pretreatment blocks (Table 7), averaging 93.1% for all treatments combined (Appendix 7). Percentage of grand fir overtopped by red alder (Figure 9) has increased since the 3rd-year assessment in all treatments but control. Form defects were not common on grand fir in any treatments (Appendix 8).

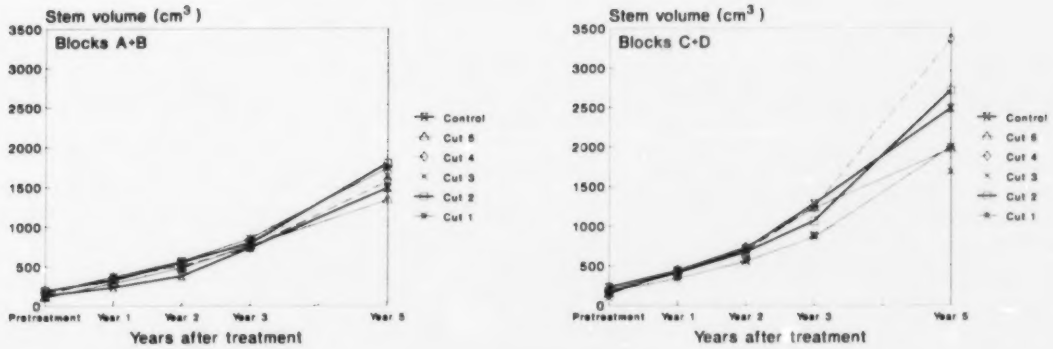

FIGURE 8. Grand fir stem volume by block, treatment, and time.

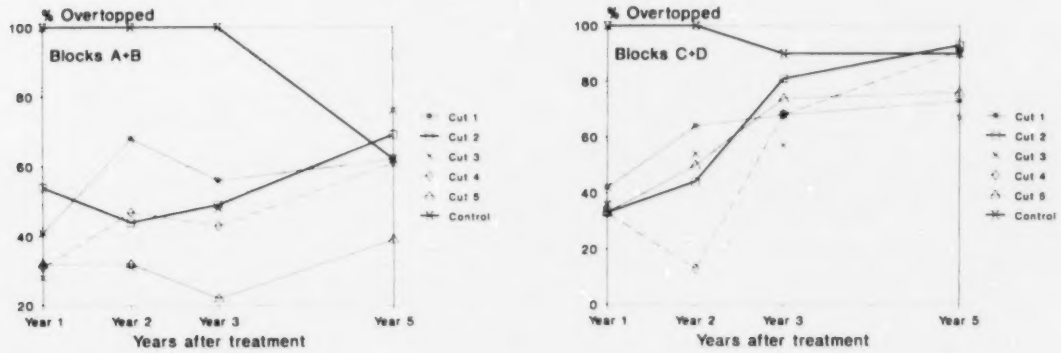

FIGURE 9. Percentage of grand fir overtopped by red alder, by block, treatment, and time.

TABLE 7. Summary of ANOVA results of 5th-year grand fir survival

Source	Error term	SS	Prob.
P	B(P)	.019	.2421
T	B(P) x T	.076	.2244
P x T	B(P) x T	.018	.3308
B(P x T)	—	.017	—
B(P)	—	.014	—

4.2.2 Douglas-fir

Before alder cutting, Douglas-fir total height and stem diameter were not significantly different between pretreatment blocks or between treatments (Appendix 9). Total Douglas-fir height is summarized in Figure 10 and total stem diameter in Figure 11.

Annual Douglas-fir height growth did not differ significantly between treatments in the first three growing seasons following cutting (Appendix 10). However, total 3-year height growth was significantly less in pretreated control plots where alder competition remained higher. Treatment differences exist for 5-year height growth and total height, but a significant treatment x pretreatment interaction indicates there were no trends between cutting period and height growth (Table 8). Douglas-fir, on average, are taller in the pretreated blocks (C+D), but the difference is not significant.

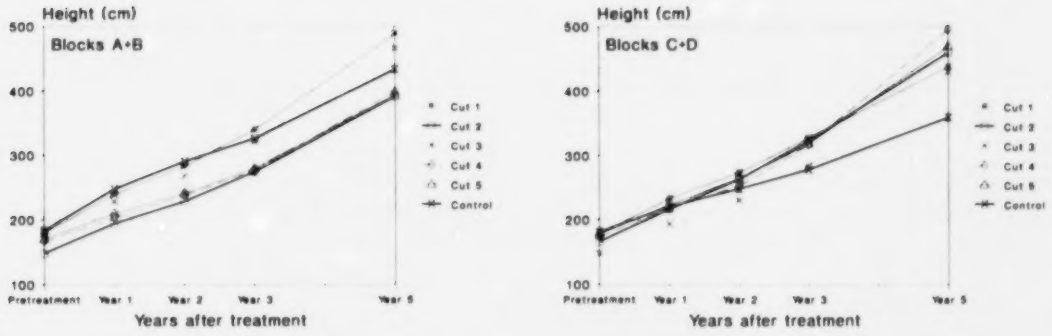

FIGURE 10. Douglas-fir total height by block, treatment, and time.

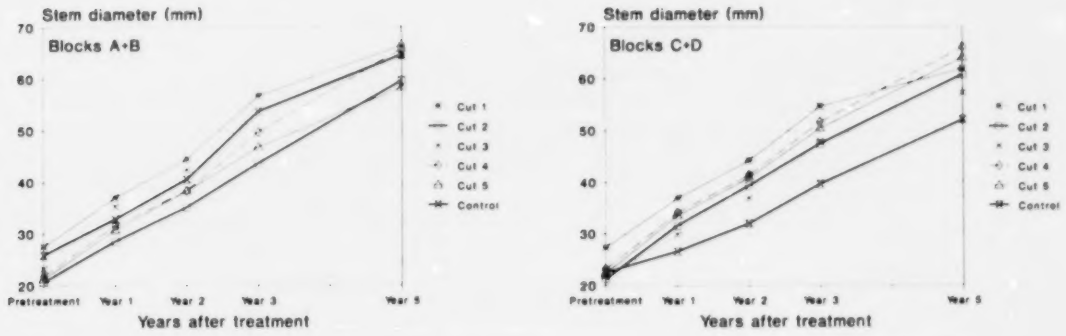

FIGURE 11. Douglas-fir stem diameter by block, treatment, and time.

TABLE 8. ANOVA results on Douglas-fir height and stem diameter: total (1988) and 5-year increment (1983-1988). Sums of squares are in parentheses.

Source	Error	Height		Diameter		Total volume 1988
		Incr. 1983-88	Total 1988	Incr. 1983-88	Total 1988	
P	B(P)	.3144 (41 251)	.2956 (57 173)	.5120 (53)	.2342 (1 307)	.8601 (340 974)
T	B(P) x T	.0058 (141 765)	.0104 (389 166)	.1259 (4 859)	.1015 (3 726)	.0404 (1.3×10^8)
P x T	B(P) x T	.0177 (101 892)	.0018 (631 776)	.9101 (612)	.0405 (5 339)	.0097 (2.6×10^8)
B(P) x T	—	— (43 062)	— (139 598)	— (4 273)	— (2 974)	— 9.1×10^7)
B(P)	—	— (46 511)	— (58 053)	— (169)	— (922)	— (1.7×10^7)

Stem diameter growth was more sensitive to alder cutting than height growth, and showed significant differences between treatments in the first and third growing seasons following treatment and for the combined 3-year stem diameter (Appendix 11). However, the five-year diameter increment was not significantly different between treatments, although diameter increment in the 4th and 5th years was strongly but not significantly affected by treatment, and a strong pretreatment x treatment interaction was apparent. Fourth- and fifth-year stem diameter growth generally decreased over the 3rd year levels, but height growth has accelerated in the final two growing seasons.

Douglas-fir volume growth (Figure 12) was significantly different between treatments, but a significant treatment x pretreatment interaction indicates trends were not consistent. Volume growth was not significantly different between blocks.

Fifth-year Douglas-fir survival was not significantly different between treatment or pretreatment blocks (Table 9), averaging 97.1% for all treatments combined (Appendix 7). Evidence of the root rot present in the mature stand has not been found on the dead saplings. Percentage of Douglas-fir saplings overtopped by red alder increased slightly since the 3rd-year assessment in most treatments, remaining highest in the blocks C+D control, which corresponds to the least volume growth (Figure 13). Douglas-fir form defects were infrequent (Appendix 8).

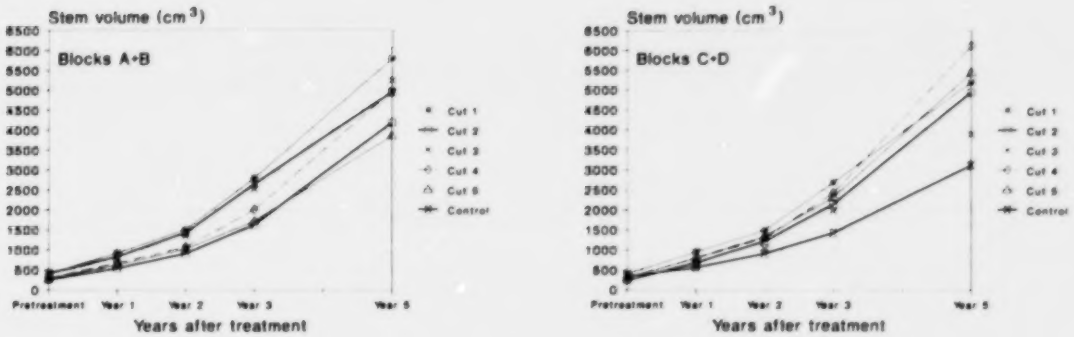

FIGURE 12. Douglas-fir stem volume by block, treatment, and time.

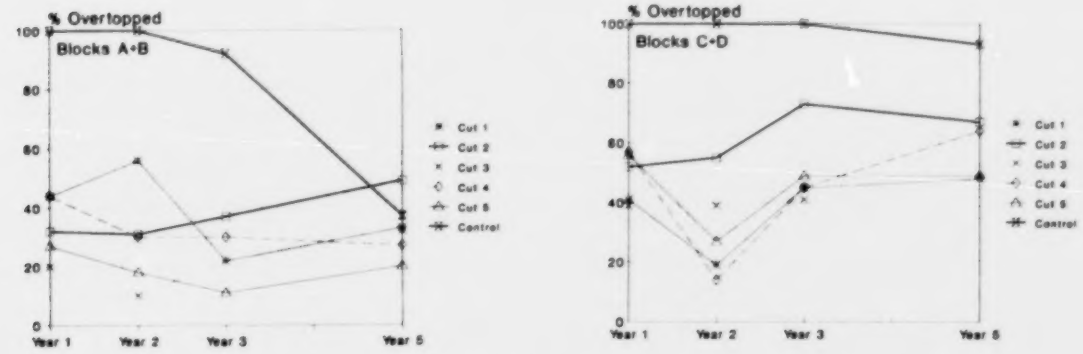

FIGURE 13. Percentage of Douglas-fir overtopped by red alder, by block, treatment, and time.

TABLE 9. ANOVA results of 5th-year Douglas-fir survival

Source	Error term	SS	Prob.
P	B(P)	.0036	.1167
T	B(P) x T	.0311	.1565
P x T	B(P) x T	.0135	.2080
B(P) x T	—	.0003	—
B(P)	—	.0016	—

5 DISCUSSION AND CONCLUSIONS

The objectives of the trial were to examine the effects of cutting time on red alder growth and on subsequent conifer growth and condition, and to suggest the most effective cutting period to minimize alder resprouting.

Hoyer and Belz (1984) found red alder mortality to be highest following cutting in July and August; Harrington (1983) found mortality was maximized during July and September cutting periods (with stumps cut low), and minimized during January cutting (with stumps cut high). Second-year results from this study suggested that cutting red alder late in the growing season resulted in greater alder mortality than did treatments earlier in the growing season. However, five growing seasons after cutting, alder survival did not differ significantly between treatments.

Alder cutting did result in a significant reduction in alder height over the 5 years of measurement. Cutting later in the growing season also led to shorter average sprout height and fewer sprouts, but differences between treatment times were not statistically significant. From the 2nd-year following treatment, alder mortality in both control and treated plots can be attributed to a combination of moisture stress in 1984 and the subsequent presence of the fungus *Melancomium*. In addition, the sparse canopy and relatively low height growth (75 cm) of the alder during the 2 previous years are substantially lower than the 1.5 m/yr height growth observed on sites with higher moisture and nutrient levels (D'Anjou 1989). This suggests that site conditions are not conducive to supporting a species that is ecologically adapted to wetter hygrotopes. Although red alder may compete with Douglas-fir for water, primarily by tapping water deeper in the rooting zone (Cole and Newton 1986), mortality observed in this study suggests that alder was more adversely affected by low soil moisture than was Douglas-fir. Chan *et al.* (1988) present similar findings.

Pretreatment densities (4400 - 51 600 stems per hectare) of alder were interfering with conifer growth. Grand fir and Douglas-fir stem diameter growth increased after alder density was reduced, whether by cutting or natural mortality. Enhanced Douglas-fir stem diameter growth following reductions in levels of competing vegetation has been identified by many researchers, including Lauterbach (1967), Gratkowski (1979), Roberts (1980), Wagner (1984), Harrington and Wagner (1986), and Jaramillo (1988). As reported in these studies, height growth and survival were not affected by reductions in alder stocking levels.

Huestis (1986) also found no height growth response (diameter growth not measured) in grand fir saplings three growing seasons after removal of overtopping alder stand. Douglas-fir is outperforming grand fir in height and stem diameter growth and survival, although the presence of root rot *P. weirii* may affect the future of Douglas-fir on this site. Both species have shown increased height growth and decreased diameter growth in years 4 and 5. Douglas-fir growth seemed largely insensitive to the range of alder densities and is displaying shade-tolerance. Grand fir, also reflecting a shade-tolerant nature, appears to benefit from some alder cover.

In addition, both conifer species have the potential to show growth benefits from alder nitrogen fixation. Nitrogen-fixing abilities of red alder can aid Douglas-fir growth on nitrogen-deficient sites (Tarrant 1961; Binkley 1982). Alder levels of 50-100 stems per hectare, suggested for supplying adequate

nitrogen yet not posing unacceptable competition to conifer growth (Miller and Murray 1977), are still below the lowest levels achieved in this trial (334 stems per hectare). Douglas-fir growth is showing the most limitations in the controls in blocks C+D where alder overtops at least 40% of the saplings and alder density remains high (5000 to 7000 stems per hectare). Although light was probably the major factor limiting conifer growth on this site before alder cutting, complete elimination of the alder overstory might not necessarily maximize conifer growth.

In summary, the following recommendations and observations can be made concerning manual cutting of red alder for release of Douglas-fir and grand fir on the study area:

1. Cut late in the growing season (before leaf fall) to maximize alder mortality. Other trials recommend cutting low to the ground with a level cut. Maximum red alder mortality achieved by manual cutting was about 90%, so in dense alder stands retreatment may be necessary to achieve desirable densities.
2. Manual cutting of alder is characterized by a narrow timing window (treatment dates weeks apart can lead to differences of several hundred alder stems per hectare). Consequently, timing is especially critical to maximize the effectiveness of manual alder cutting.
3. Pretreatment densities of alder (4400-51 600) inhibited Douglas-fir and grand fir growth. Initial growth response of both conifer species following alder treatment was in stem diameter.
4. The abilities of alder to fix nitrogen and to return considerable amounts of organic matter to the soil should be considered before complete alder removal is decided as the vegetation management course on nutrient-poor sites. Research is needed to determine the relationship between alder density and conifer growth on these drier sites so that more objective vegetation management decisions can be made.

6 REFERENCES

Binkley, D. 1982. Case studies of red alder and sitka alder in Douglas-fir plantations: nitrogen fixation and ecosystem production. Ph.D. thesis. Oreg. State Univ., Corvallis, Oreg. 115 p.

Chan, S.S., S.R. Radosevich, and J.D. Walstad. Carbon allocation, morphology and physiology of Douglas-fir and red alder saplings in response to light and soil moisture availability. *In* Vegetation competition and response: Proc. 3rd Ann. Vegetation Manage. Workshop. E. Hamilton and S. Watts (compilers). B.C. Min. For., FRDA Rep. 26.

Cole, E.C. and M. Newton 1986. Nutrient, moisture and light relations in 5-year-old Douglas-fir plantations under variable competition. Can. J. For. Res. 16:727-732.

Conway-Brown, M. 1985. Manual control of red alder with clearing saws: operations report and equipment assessment. B.C. Min. For., Silv. Branch, Victoria, B.C. 46 p.

D'Anjou, B.N. 1989. Evaluation of the herbicides sulfometuron methyl, hexazinone, and metsulfuron methyl and the manual removal of non-crop vegetation as conifer release treatments. Third-year progress report. B.C. Min. For., FRDA 2.15.

Gratkowski, H. 1979. Growth of Douglas-fir after release from snowbrush. *In* Effects of competing vegetation on forest trees: a bibliography with abstracts. Wash. Dep. Agric., For. Serv., 1984.

Harrington, C.A. 1983. Factors influencing initial sprouting of red alder. U.S. Dep. Agric., For. Sci. Lab., Olympia, Wash.

Harrington, T.B. and R.G. Wagner. 1986. Three years of Douglas-fir growth and survival following six competition release treatments in the Oregon and Washington Coast Range. Oreg. State Univ., For. Res. Lab., Corvallis, Oreg.

Hoyer, G.E. and D. Belz. 1984. Stump sprouting related to time of cutting red alder. Wash. Dep. Natural Resources. DNR Rep. 45.

Huestis, D.E. 1986. Growth response of grand fir to release from competing red alder by the herbicide Roundup. B. Sc. thesis. Univ. B.C., Vancouver, B.C.

Jaramillo, A.E. 1988. Growth of Douglas-fir in Southwestern Oregon after removal of competing vegetation. U.S. Dep. Agric., Pac. For. Res. Sta., Res. Note PNW-RN-470.

Kovats, M. 1977. Estimating juvenile tree volumes for provenance and progeny testing. Can. J. For. Res. 7: 335-342.

Krajina, V.J., K. Klinka, and J. Worrall. 1982. Distribution and ecological characteristics of trees and shrubs of British Columbia. Univ. B.C., Faculty For., Vancouver, B.C. 130 p.

Lauterbach, P.G. 1967. Chemical weeding and release of conifers in western Oregon and Washington. *In* Proc. Conf. on Herbicides and Vegetation Management. Oreg. State Univ., School For., Corvallis, Oreg. pp. 148-151.

Miller, R.E. and M.D. Murray. 1977. The effects of red alder on growth of Douglas-fir. *In* Utilization and management of alder. D.G. Briggs, D.S. Debell, and W. Atkinson (compilers). U.S. Dep. Agric., For. Serv., Pac. NW For. Range Exp. Sta., Portland, Oreg. Gen. Tech. Rep. PNW-70, pp. 283-306.

Roberts, C. 1980. Cooperative brush control study: second-year report. Reforestation consultant, Corvallis, Oreg.

Tarrant, R.F. 1961. Stand development and soil fertility in a Douglas-fir - Red alder plantation. For. Sci. 7(3):238-246.

Wagner, R.G. 1984. Growth and survival of Douglas-fir two years following six release treatments in the Oregon and Washington coast range. Oreg. State Univ., For. Res. Lab., Corvallis, Oreg.

Zar, J.H. 1984. Biostatistical analysis. Prentice-Hall, Inc., New York, N.Y.

APPENDIX 1. Description of planting stock

Species	Bg	F
Seedlot	854	3208
Stock type	2+0 Br	2+0 Br
Producing nursery	Campbell River	Surrey
Date lifted	Mar. 14/79	Feb. 27/79
Date planted	Mar. 21-28/79	Mar. 21-28/79
Stock condition:		
Good	90%	90%
Multiple leaders	5%	5%
Spindly	5%	5%

APPENDIX 2. Weather records (1983) for the first four treatment periods

Date		Temp. (°C)	Relative humidity	Time of reading
June	7	23	61	1300
	8	26	54	1300
	9	17	76	1300
July	5	23	53	1415
	6	24	56	1500
	7	18.5	55	1300
July	19	27	64	1300
	20	17.5	77	1300
	21	0.5	67	1305
Aug.	2	26	53	1300
	3	25	57	1430
	4	23	60	1300

APPENDIX 3. Conifer condition codes

(i) Condition Codes

1 = Severed
2 = Damaged
3 = Covered by debris
4 = Free growing

(ii) Tree Class

1 = Residual
2 = Suspect
3 = Dead

(iii) Pathological Code

S = Scar
F = Fork or crook
D = Dead or broken

(iv) Subsequent Condition

1 = Chlorotic
2 = Seedling toppled
3 = Sun scald
4 = Insect damage
5 = Disease damage
6 = Animal damage
7 = Covered by debris
8 = Dieback of terminal or lateral growth

APPENDIX 4. ANOVA of grand fir pretreatment stem diameter and height

Source	Term	Pretreatment height		Pretreatment diameter	
		SS	Prob.	SS	Prob.
P	B(P)	9 034	.333	126	.109
T	B(P) x T	10 144	.736	151	.604
P x T	B(P) x T	14 439	.585	101	.767
B(P) x T	—	36 936	—	402	—
B(P)	—	9 840	—	74	—

APPENDIX 5. ANOVA results of grand fir stem diameter increment, by growing season. Sums of squares are in parentheses.

Source	Error	Stem diameter increment		
		1st Year	2nd Year	3rd Year
P	B(P)	.355 (8.4)	.596 (1.4)	807 (2.0)
T	B(P) x T	.051 (470)	.195 (73.5)	.034 (375)
P x T	B(P) x T	.892 (45)	.985 (4.8)	.525 (87)
B(P) x T	—	— (280)	— (80.4)	— (196)
B(P)	—	— (15)	— (3.2)	— (35)

APPENDIX 6. ANOVA of grand fir height increment, by growing season. Sums of squares are in parentheses.

Source	Error	Height increment		
		1st Year	2nd Year	3rd Year
P	B(P)	.678 (71.4)	.100 (624)	.030 (6250)
T	B(P) x T	.187 (3530)	.213 (1500)	.212 (5230)
P x T	B(P) x T	.187 (3530)	.880 (290)	.190 (5550)
B(P) x T	—	— (860)	— (1730)	— (5980)
B(P)	—	— (3780)	— (420)	— (1590)

APPENDIX 7. Fifth-year conifer survival and sample size by species, pretreatment status, and treatment

(I) Grand fir

Blocks	Treatment					
	Cut 1	Cut 2	Cut 3	Cut 4	Cut 5	Control
A+B	100 (34)	95 (40)	92.6 (27)	82.9 (35)	94.7 (19)	92.9 (14)
C+D	91.7 (24)	100 (27)	96.4 (28)	91.7 (24)	81.0 (21)	100 (10)
Total	96.6 (58)	97 (67)	94.5 (55)	86.4 (59)	83.3 (40)	95.8 (24)

(II) Douglas-fir

Blocks	Treatment					
	Cut 1	Cut 2	Cut 3	Cut 4	Cut 5	Control
A+B	100 (66)	98.3 (50)	98.6 (70)	93.7 (63)	97.5 (80)	96 (25)
C+D	98.7 (76)	97.3 (73)	98.6 (72)	98.7 (75)	94.9 (78)	93.3 (30)
Total	99.3 (142)	97.7 (133)	98.6 (142)	96.3 (138)	96.8 (158)	94.5 (55)

APPENDIX 8. Fifth-year condition of saplings by species, treatment, and block. Figures are percent of live saplings.

Blocks	Grand fir			Douglas-fir			
	Broken top	Fork	Dead top	Broken top	Fork	Dead top	Scars
Blocks A+B							
Cut 1	3	3	0	0	0	0	1
Cut 2	0	5	0	0	0	0	0
Cut 3	4	0	0	1	0	0	0
Cut 4	0	0	3	0	0	0	0
Cut 5	0	0	6	0	0	0	0
Control	0	0	0	0	0	4	0
Blocks C+D							
Cut 1	0	0	0	0	0	0	0
Cut 2	0	0	0	0	0	0	0
Cut 3	0	0	0	0	0	1	0
Cut 4	0	5	0	0	0	0	0
Cut 5	0	12	0	0	0	0	1
Control	0	0	0	0	2	0	0

APPENDIX 9. ANOVA of pretreatment height and stem diameter of Douglas-fir saplings

Source	Error term	Pretreatment height		Pretreatment diameter	
		SS	Prob.	SS	Prob.
P	B(P)	1 344	.506	30	.398
T	B(P) x T	43 300	.123	1 503	.126
P x T	B(P) x T	52 288	.080	455	.015
B(P) x T	—	37 671	—	1 044	—
B(P)	—	4 165	—	116	—

APPENDIX 10. ANOVA of Douglas-fir height growth, by growing season. Sums of squares are in parentheses.

Source	Error term	Height increment		
		1st Year	2nd Year	3rd Year
P	B(P)	.319 (1 670)	.827 (35.0)	.078 (6 490)
T	B(P) x T	.050 (17 920)	.026 (5 765)	.258 (15 350)
P x T	B(P) x T	.442 (5 630)	.006 (8 830)	.218 (16 960)
B(P) x T	—	— (10 750)	— (2 750)	— (5 980)
B(P)	—	— (3 060)	— (2 280)	— (1 590)

APPENDIX 11. ANOVA of Douglas-fir stem diameter increment, by growing season. Sums of squares are in parentheses.

Source	Error term	Stem diameter increment		
		1st Year	2nd Year	3rd Year
P	B(P)	.556 (25)	.216 (11)	.385 (190)
T	B(P) x T	.0003 (1160)	.330 (104)	.001 (540)
P x T	B(P) x T	.060 (260)	.678 (50)	.020 (230)
B(P) x T	—	— (166)	— (158)	— (103)
B(P)	—	— (116)	— (18)	— (370)